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Managing the Strategic Transformation of Higher Education through Artificial Intelligence

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Abstract: Considering the rapid advancements in artificial intelligence (AI) and their potential implications for the higher education sector, this article seeks to critically evaluate the strategic adoption of AI in the framework of "smart universities". We envisage these innovative institutions as the imminent evolution in higher education, harnessing AI and quantum technologies to reshape academic and administrative processes. The core presumption is that through such integration, universities can achieve personalized learning trajectories, enhanced accessibility, economic efficiency, and a boost in overall operational performance. However, venturing into this new educational paradigm necessitates a thorough exploration of potential pitfalls, including questions surrounding educational quality, potential job losses, risks of bias, privacy breaches, and safety concerns. Our primary objective is to offer a balanced assessment to aid stakeholders in making informed strategic decisions about endorsing and advancing the smart university model. A pivotal factor in this discourse is the acceptance of qualifications from AI-enriched institutions by employers, a variable that may drastically redefine the education sector's trajectory. Within the context of a comprehensive analysis of its broader societal impact, this article also delves into the ramifications of AI-driven innovations for historically Black colleges and universities (HBCUs).

Keywords: artificial intelligence; smart university; strategic management; digital transformation; educational sustainability; HBCUs; quantum technologies; change management; future of education

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1. Introduction

In recent years, artificial intelligence (AI) has made significant strides in various industries, including education (Arogundade 2023; George and Paul 2020). The higher education sector is increasingly recognizing AI as a source of competitive advantage (Hannan and Liu 2021). The idea of a "smart university", powered by AI and able to perform most tasks autonomously, is becoming more achievable due to advancements in machine learning and natural language processing (NLP) technologies (Furey and Martin 2019). Such institutions have the potential to automate administrative duties, curriculum development, instruction, assessment, and even the issuance of transcripts and degrees (Hannan and Liu 2021).

One key advantage of an AI-centered smart university is its potential to lower costs, while enhancing efficiency and accessibility (Schiff 2021). AI systems can handle admissions, enrollment, and course scheduling, thus reducing the workload for administrative staff. This decrease in variable costs, combined with the potential for tailored curriculum offerings, augments accessibility. Moreover, AI systems can design and deliver lessons, assess student performance, and provide personalized feedback. This allows faculty members to focus more on research and other responsibilities (Heilinger et al. 2023). Another advantage of a smart university is its ability to individualize the learning experience for each student (Siirtola and Röning 2019). By examining student performance data, AI systems can modify lessons to address the distinct needs of every learner, a fact underscored by the successful deployment of AI-powered tutors in online learning platforms.

The conceptual blueprint of the administrative system of an AI-powered smart university is given in Figure 1.

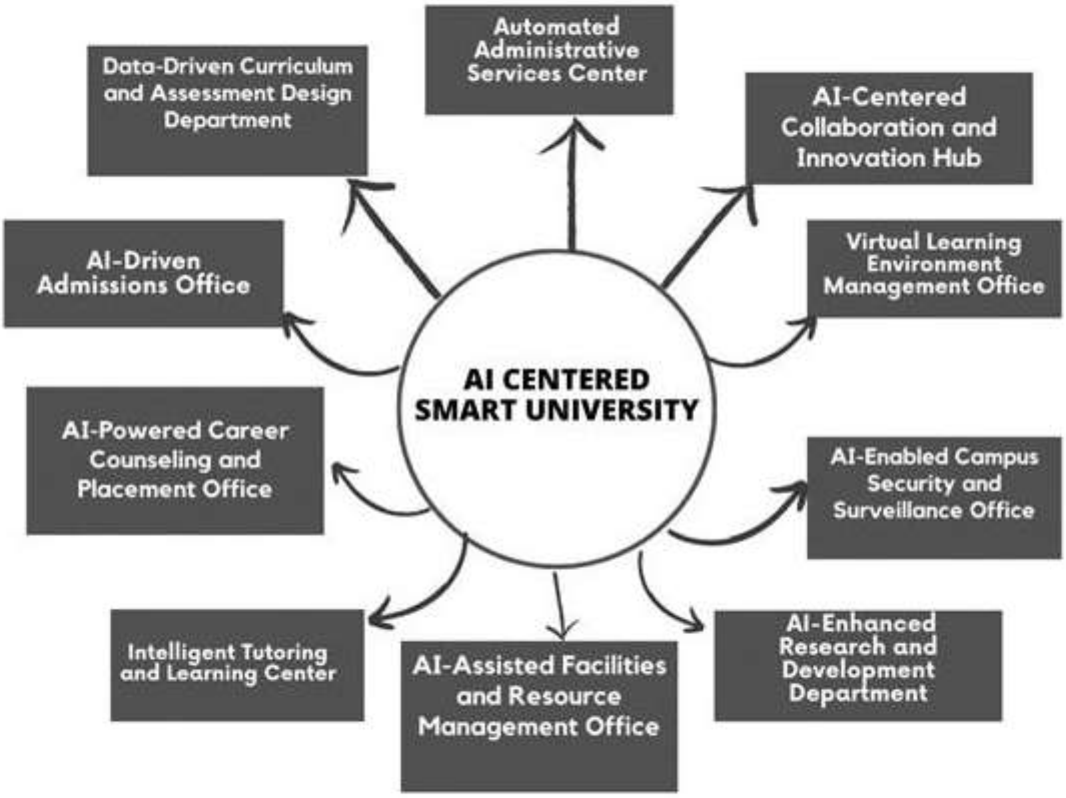

Figure 1. The administrative system blueprint of an AI-centered smart university.

1.1. Objectives of the Study

The objectives of the study are:

- To provide a comprehensive review of the current and emerging applications of AI in higher education, capturing the evolution and present state of this dynamic landscape.
- To outline the theoretical design and functional aspects of a smart university—an envisioned higher education institution that leverages advanced quantum AI technologies for near-autonomous operation.
- To explore the potential roles and responsibilities of a smart university in enhancing the educational experience and decentralizing credible credentialing.
- To analyze the challenges and opportunities of integrating AI in the higher education framework, with a particular emphasis on management and administration strategies.
- To challenge prevailing educational paradigms, advocating for a transformative shift in stakeholder roles and collaboration dynamics in the face of AI-driven changes.

1.2. Contribution to Higher Education and Artificial Intelligence

This study stands at the nexus of higher education and artificial intelligence, offering a forward-looking perspective seldom addressed comprehensively in existing literature. By synthesizing a vast body of research and projecting future possibilities, we:

- Illuminate the transformative potential of AI in reimagining higher education institutions, bringing to the fore the concept of an almost fully autonomous smart university.
- Provide a roadmap for stakeholders, from educators to administrators, highlighting the necessity of strategic planning and proactive approaches in navigating the AI-driven evolution of higher education.

- Emphasize the unparalleled benefits of AI in addressing contemporary educational challenges, ranging from tailored learning experiences to streamlined administrative processes.
- Present a call to action, urging a reevaluation of conventional educational models and collaboration methodologies, ensuring higher education remains relevant, resilient, and responsive in an AI-augmented era.

2. Methodology

A mix of systematic review, meta-analysis, and narrative review methodologies was used. This integrated method ensures thorough coverage of current material, while adhering to strict academic standards. An empirical study based on primary data is not feasible because the space of inquiry is still explorative. Only rudimentary elements of AI-driven smart universities are in existence now, and a comprehensive study of this nature ought to be conceptual in nature.

2.1. Literature Search and Selection Criteria

The current literature provides rich insights into the state of digital interventions in education, from the inception of online learning platforms to the more nuanced applications of AI for personalized learning and administrative automation. However, the literature did not anticipate the surge of AI as we see it now. Even as digital transformation was discussed extensively, research in the past did not place AI at the centerstage of disruptions in higher education. The literature search for this paper was conducted with the objective of readjusting the narratives in the light of the generative AI revolution and futuristic predictions around it.

The investigation began with a thorough search for relevant papers using academic search engines, such as Google Scholar, Scopus, Web of Science, Semantic Scholar, and Microsoft Academic. The search parameters were created with terms connected to the topic of interest in mind, such as "artificial intelligence", "higher education", "future of universities", "AI in education", "HBCUs and technology", and "technology in academia".

2.2. Inclusion and Exclusion Criteria

The majority of the papers included in this study were published in 2019 or later and indexed in respected databases, such as SCOPUS or Web of Science, to ensure their currency and quality. Excluded were studies that did not focus on AI or its implications in the setting of higher education.

2.3. Data Extraction and Thematic Identification

The researchers thoroughly studied and summarized each paper after finding those that fulfilled the selection criteria. During this procedure, recurring themes and patterns were recognized, allowing the information to be organized into coherent categories. This method allowed the researchers to collect a wide range of opinions and thoughts on the research issue.

2.4. Data Analysis and Synthesis

In this study, no qualitative analytic software was used to analyze data. Instead, the researchers gathered essential data and material from each article by hand and combined those data into theme summaries. These topics were then examined to identify similarities, contradictions, and developing patterns in the body of literature. The researchers obtained informed thoughts about the future of AI in universities and its possible influence on higher education as a result of this synthesis.

2.5. Ethical Considerations

Ethical issues were considered throughout the study procedure. Because this was a review of the literature, no human subjects were used and no personally identifying information was presented. The researchers followed academic integrity rules, ensuring that all sources were correctly credited and that any possible conflicts of interest were mentioned.

This analytical approach assisted us in developing a thorough grasp of the role of AI in the future of universities. This review's findings will be a great resource for academics, educators, policymakers, and other stakeholders interested in AI's transformational potential in higher education.

3. Managing Digital Transformation in Higher Education: A Brief History

The digital transformation of universities has evolved gradually, commencing in the late 20th century and gaining momentum in recent years (Rodríguez-Abitia and Bribiesca-Correa 2021; Kroshilin 2022; Teker et al. 2022; Maltese 2018; Payr 2003). From the initial stages of using computers and the internet to streamline administrative functions to today's era of AI-driven personalized learning, universities have consistently leveraged digital technology to enhance educational quality, making it more accessible and cost-effective for students. The following is a succinct chronicle of this transformation, with the integration of AI in higher education marking its latest evolution:

1. Early years (late 20th century): The digital transformation of universities began with the introduction of computers and the internet. In these early years, universities used these technologies to automate administrative tasks and to share information through email and online portals. The focus was on efficiency and communication.
2. Online learning (early 2000s): As the internet became more accessible, universities began to offer online courses. These courses allowed students to learn remotely and at their own pace. Initially, online courses were limited to certain fields of study, such as computer science and business, but they eventually expanded to other fields as well.
3. Massive open online courses (MOOCs) (2010s): The next phase of digital transformation was the introduction of MOOCs. These are free online courses that anyone can take. MOOCs are often taught by professors from top universities and are designed to be accessible to anyone with an internet connection. MOOCs have revolutionized higher education by making it more accessible and affordable.
4. Learning management systems (LMSs) (2010s): The next phase of digital transformation was the widespread adoption of learning management systems (LMSs). LMSs are software applications that help universities manage their online courses and facilitate communication between students and instructors (e.g., Blackboard, Moodle, Canvas). Students may access course materials through an LMS, turn in assignments, and communicate with their professors and other students.
5. Personalized learning (2010s): With the advent of big data and analytics, universities began to explore personalized learning. Personalized learning uses data on students' learning styles, preferences, and performance to tailor their education to their individual needs. This approach to learning has the potential to increase student engagement and improve learning outcomes.
6. Artificial intelligence (AI) (2020s): The latest phase of digital transformation in higher education is the integration of artificial intelligence (AI). AI has the potential to revolutionize higher education by providing personalized feedback to students, automating administrative tasks, and improving the quality of education. AI can also be used to predict student performance, identify at-risk students, and offer early interventions to help them succeed. More recent advances in quantum technologies increase the scale and scope of this transformation.

4. Key Subsystems of an AI-Centric Smart University

Key subsystems:

- An AI university could be characterized as a higher education institution that uses artificial intelligence technologies to refine its functions and operations. This entails integrating AI across research, administration, teaching, and learning domains to bolster efficiency, effectiveness, and personalization.

- The paramount objective of an AI-centric smart university is to amplify the caliber of the educational journey for students, while simultaneously promoting knowledge generation and innovation via AI. Such universities aim to foster an ambience wherein students can interact with sophisticated AI tools and technologies, acquire pertinent skills in the AI domain, and apply these to tangible challenges. A significant emphasis is also placed on collaboration and industry partnerships, ensuring the institution remains abreast of the most recent AI advancements and that its graduates are primed with the requisite expertise for their subsequent professional endeavors.
- These academic establishments will harness advanced AI systems capable of executing an array of functions, spanning administrative roles, like admissions, enrollment, and grading, to academic endeavors, such as curriculum development, lesson delivery, and research. Integral to these universities are several core components, as indicated by Bera (2019), Choi and Kim (2021), and Gould (2019):
- Learning management systems: The university will feature a cutting-edge learning management system that allows students to access course materials, submit assignments, and engage with peers and instructors. This system will also cater to personalized learning experiences tailored to each student's needs and capabilities.
- Virtual reality and simulation technologies: The university will harness virtual reality and simulation technologies to craft vivid and immersive learning settings. This approach will allow students to immerse themselves in real-world scenarios, thus deepening their comprehension and engagement.
- Robotic and automated systems: The university will deploy various robotic and automated systems for routine operations, enabling AI systems to concentrate on intricate responsibilities.
- Data management systems: Equipped with sophisticated data management systems, the university will have the capacity to archive, process, and scrutinize extensive data sets. Such capabilities empower AI systems to render informed choices and continually refine their functions.
- Sensors and monitoring systems: A myriad of sensors and monitoring devices will be integrated throughout the university, collecting data on the surroundings, student activities, and facilities. These data will aid in optimizing university operations and ensuring a conducive and secure educational atmosphere.
- Renewable energy systems: Prioritizing sustainability, the university will draw its power from renewable energy sources, such as solar and wind, underlining its commitment to eco-friendliness.

By integrating these technologies, an AI-powered and AI-managed university will operate predominantly autonomously, providing students with personalized, high-quality education in a sustainable and safe environment without the need for human intervention.

5. From Learning Management Systems to Intelligent Tutoring Systems

The benefits of integrating artificial intelligence technologies into educational structures, particularly in learning management systems (LMSs) and intelligent tutoring systems (ITS), are significant (Manju and Anilkumar 2020). A learning management system is a software tool designed for the management, delivery, and monitoring of educational content and resources. Within an AI-enhanced university environment, there is potential for substantial improvements in LMSs, elevating both the student learning experience and academic outcomes (Firat 2023). Specifically, AI-driven LMSs can use machine learning algorithms to craft personalized learning paths for students, adapted to their unique needs and learning patterns. Moreover, these systems can analyze student performance data to offer tailored feedback and guidance, enhancing academic achievement. Additionally, they can automate tasks such as grading and tracking attendance, allowing educators to dedicate more time to teaching and mentoring students.

AI-enhanced LMSs can incorporate a wide range of AI methodologies, such as natural language processing and computer vision, to augment their capabilities (Bernacki 2016).

For instance, natural language processing can analyze students' written work, providing automated feedback on elements like grammar, spelling, and sentence construction. Additionally, computer vision can assess facial expressions and body language to gauge students' emotional states, ensuring timely assistance and resource provision. In summary, AI-infused LMSs offer the potential to significantly elevate student educational experiences and academic paths by crafting individualized learning experiences, simplifying administrative tasks, and strengthening the support mechanisms for students' development and well-being.

Intelligent tutoring systems (ITS) use AI to provide students with individualized training and feedback. ITS are designed to replicate a one-on-one tutoring experience, adapting to the student's unique learning style, pace, and performance (Bradáč and Kostolányová 2016). The system collects data on the student's performance, such as their responses to quizzes and assignments, and uses this information to identify areas where the student requires additional support. Based on this analysis, the system generates personalized learning materials and provides targeted feedback to the student, including hints, explanations, and corrective feedback.

One of the primary advantages of ITS is the ability to provide individualized instruction to students, a benefit that is not feasible in traditional classroom settings. ITS allows students to work at their own pace and receive targeted support, when needed, without having to wait for the teacher's assistance. Additionally, ITS can adapt to the student's learning style, such as providing visual aids and examples for visual learners, thereby improving student engagement and retention of the material. Intelligent tutoring systems offer a promising application of AI in education, with the potential to improve academic outcomes and provide personalized support to students.

6. Adaptive Testing

Adaptive testing is a type of assessment that uses AI algorithms to dynamically adjust the difficulty level of questions based on a student's responses in real time (Sinharay 2016). This type of testing is designed to provide a more accurate measure of a student's knowledge and abilities than traditional fixed-form tests (Yurtcu and Guzeller 2021). In adaptive testing, the AI algorithm starts by presenting the student with a question of moderate difficulty. Based on the student's response, the algorithm determines the level of knowledge the student possesses and adjusts the difficulty level of the next question. If the student answers correctly, the algorithm will present a more challenging question, whereas if the student answers incorrectly, the algorithm will present an easier question. The process continues until the algorithm accumulates sufficient data to accurately determine the student's capability. By tailoring the question's difficulty, adaptive testing can offer a more precise evaluation of a student's knowledge and skills compared to conventional static tests (Dai et al. 2022).

The benefits of adaptive testing are numerous (Van der Linden and Glas 2000). First, it can save time and increase the efficiency of testing by allowing students to answer fewer questions without sacrificing accuracy. Second, it can provide a more accurate assessment of a student's abilities, especially for students with diverse learning needs. Adaptive testing can also help teachers identify areas where students need additional support, allowing for more targeted and effective instruction. Adaptive testing is a powerful tool that uses AI to improve the accuracy and efficiency of assessments, making it an increasingly popular option for educators and educational institutions.

7. Virtual Reality and Metaverse in the AI University System

The incorporation of virtual reality (VR), augmented reality (AR), and extended reality (XR) technologies into education and learning can have a transformative impact by providing immersive and interactive learning experiences (Reiners et al. 2021). In an AI-powered university, these technologies can be integrated with AI to enhance their capabilities and offer personalized learning experiences (Luck and Aylett 2000). An AI-powered university can use VR, AR, and XR technologies to provide students with immersive and interactive learning experiences. These technologies can simulate real-life scenarios, such as medical procedures or engineering design projects, allowing students to gain practical skills in a safe and controlled environment (Akour et al. 2022). Furthermore, AI can personalize these experiences according to an individual student's learning styles and preferences, providing customized feedback and support to enhance their learning outcomes. In addition, AI can enhance the capabilities of VR, AR, and XR technologies (Ahmet 2022; Bhavana and Vijayalakshmi 2022). For instance, AI can track and analyze students' eye movements and interactions with the environment to provide real-time feedback and adapt the learning experience to their needs. Moreover, AI can analyze students' performance data and provide personalized recommendations and resources to support their learning. By combining these technologies with AI, universities can offer personalized and immersive learning experiences that enhance students' learning outcomes and practical skills.

In recent years, AI has played a significant role in the futuristic development of "reality technologies". The combination of these technologies has given rise to the concept of the "Metaverse" (Buana 2023; Cai et al. 2022). The Metaverse is a virtual world that exists parallel to the physical world, where users can interact with each other in real time using their digital avatars (Kshetri et al. 2022). It offers endless possibilities for entertainment, education, and socialization, among other things (Vita-More 2010). The Metaverse is a technology that has been under development for some time, and several major companies, such as Meta, Microsoft, and Alphabet, have invested heavily in it, with AI playing an important role in its advancement. AI-powered natural language processing (NLP) algorithms can analyze and understand user intent to generate responses that feel natural and human-like, while AI-powered computer vision algorithms can recognize and track user movements and gestures, creating realistic and immersive experiences. Additionally, machine learning algorithms can analyze user data to personalize their experiences in the Metaverse (Shen 2022).

The potential implications of the Metaverse for higher education are significant (Zhai et al. 2022). Virtual classrooms can be created in the Metaverse, providing a more engaging and interactive learning experience. Virtual environments can be created for students to collaborate on projects and assignments, which can help them develop important skills. Additionally, personalized learning experiences can be created in the Metaverse by analyzing student data and identifying areas of strength and weakness to make recommendations that align with their learning style.

AI has played a crucial role in the development of the Metaverse, which has the potential to revolutionize higher education by providing immersive and interactive learning experiences. Metaverse technology is still in its early stages, but it will continue to evolve and shape the future of education (Kongpha and Chatwattana 2023).

8. The Omnipresence of Chatbots

Artificial-intelligence-powered chatbots, using NLP to engage in conversations with humans, have seen a rise in popularity across diverse sectors, including higher education (Okonkwo and Ade-Ibijola 2021; Lin and Yu 2023). In the realm of higher education, chatbots can assume various roles, ranging from enhancing student engagement and support and delivering personalized assistance to boosting administrative efficiency (King 2023; Kagan et al. 2022).

For student engagement and support, chatbots are equipped to address commonly posed questions, furnish details about courses and programs, and guide students through the myriad of institutional resources and services. By evaluating student data and interaction trends, chatbots can also proffer personalized course and program suggestions, aiding students in charting informed academic journeys. On the administrative front, chatbots can streamline tasks such as handling admissions, managing financial aid applications, organizing advisor appointments, and garnering student feedback. This automation allows the administrative staff to dedicate their efforts to more intricate responsibilities, enhancing the institution's operational efficiency. Beyond the student life cycle, chatbots can play a pivotal role in sustaining connections with alumni by disseminating updates on institutional milestones and events, extending career guidance and job prospects, and promoting philanthropic endeavors.

However, it is important to note that chatbots would not replace human interaction and support entirely (Vanichvasin 2022). While chatbots can provide quick and efficient responses to simple queries, they cannot replace the empathy and personal touch that only humans can provide (Kooli 2023; Dimitriadis 2020). Therefore, colleges should strive to strike a balance between using chatbots to improve efficiency and providing human support when it is needed (Winkler and Söllner 2018). Overall, chatbots have the potential to play a significant role in higher education by improving student experiences and administrative operations, but their use should be carefully considered and balanced with human support to ensure the best outcomes for students and the college community (Bhunu Shava et al. 2023; Ouyang and Jiao 2021).

9. Management of Learning in the Era of AI

The prospective advantages of AI's role in continuous learning have been investigated across diverse professions (McMillan 2020; Smith and Severn 2022). In a self-sustaining university equipped with AI-driven data management systems, extensive data pertaining to students, faculty, staff, and other stakeholders can be accumulated and assessed. This allows for the enhancement of performance and facilitates data-informed decision making (Srinivasan 2022). Specific applications of this are described next.

9.1. Identifying Student Needs

AI-powered data management systems can gather and analyze data on student performance to identify areas where students may be struggling. For example, data on grades and test scores can pinpoint courses where students need extra support. The university can then provide tailored assistance to help these students succeed, based on their individual needs. Additionally, student feedback data can be used to improve the overall student experience.

9.2. Improving Teaching

AI-powered data management systems can also gather and analyze data on faculty performance, such as student feedback. The bias of self-reported data has always been a problem in teaching effectiveness evaluations; AI may provide relevant inputs for triangulation. This can help identify areas where faculty members may need additional support or training to improve their teaching skills.

9.3. Optimizing Resource Management

Data on resource usage, such as energy consumption, can be analyzed to optimize resource management in a self-sustaining university. By identifying areas where energy usage can be reduced, the university can implement measures to conserve energy and reduce costs.

By leveraging AI-powered data management systems, a self-sustaining university can continuously learn from the data it gathers to identify areas for improvement and implement measures to enhance student outcomes, improve teaching, and optimize resource management (Sein Minn 2022; Bognár and Fauszt 2022; Ingkavara et al. 2022).

10. AI in Knowledge Discovery

There are various ways in which AI can augment academic research, as outlined in studies by de Jong and Bus (2023), Wade and Wang (2016), and DesRoches (2022). These include:

1. Literature review: AI can automate the process of conducting a literature review by analyzing vast amounts of data and extracting relevant information from those data. This can save researchers considerable time and effort.

2. Data analysis: Large data sets may be analyzed by AI to find patterns and trends that human researchers might not see right away. This can help researchers make more informed decisions and draw more accurate conclusions.
3. Prediction and forecasting: AI can develop predictive models that forecast future trends or outcomes based on historical data. This can be particularly useful in fields such as economics, finance, and medicine.
4. Experiment design: AI can help researchers design experiments by identifying variables that may impact the outcome and suggesting optimal values for those variables.
5. Collaboration: AI can facilitate collaboration among researchers by analyzing their work and identifying areas where they can work together to achieve common goals.

AI has the potential to significantly improve the efficiency and effectiveness of academic research by automating tedious tasks, providing new insights, and enabling collaboration. However, it is important to remember, at least for now, that AI should be used as a tool to assist researchers, not as a replacement for human expertise and creativity, as highlighted by Ridley (2022).

The use of AI in academic research raises several ethical concerns that require consideration (Dagher 2022; Kennedy 2019). Some of these include:

1. Privacy and data protection: The use of large amounts of data in AI research requires compliance with data protection regulations to ensure participant privacy.
2. Bias and fairness: Bias can result from non-representative data, leading to unfair outcomes and discrimination. Researchers should strive to mitigate bias in their data and algorithms and ensure fairness.
3. Transparency and explainability: AI systems can be difficult to understand and explain, and researchers should aim for transparency and explainability.
4. Informed consent: Participants should be fully informed about the research and provide informed consent before participating.
5. Accountability and responsibility: Researchers have a responsibility to ensure that their use of AI is ethical and socially responsible and to be accountable for any negative effects of their research.
6. Intellectual property: The creation of new intellectual property raises questions of ownership, authorship, and licensing.
7. Human oversight: AI systems should not replace human decision making without human oversight.

Researchers must recognize the ethical issues associated with using AI in academic research and take steps to address them (Hine 2021). By doing so, they can ensure that their research is conducted ethically and with social responsibility.

11. Educational Data and Analytics

Artificial intelligence has revolutionized data management systems (DMS), enhancing their efficiency, reliability, and speed (Wang 2021a, 2021b). This advancement in AI-driven DMS has paved the way for the realization of a self-sustained university. Such a university, underpinned by AI-operated DMS, can make insightful decisions, augment efficiency, and amplify student experiences (Wang 2021a, 2021b). The incorporation of AI-driven DMS in a self-sustained university entails the deployment of sophisticated algorithms capable of processing immense volumes of data instantaneously (Okewu et al. 2021). Machine learning techniques facilitate data analysis, drawing pivotal insights for informed decision making. Furthermore, the adaptive nature of AI empowers DMS to evolve based on previous experiences, refining efficiency as time progresses (Jiang and Naumov 2022). A notable merit of AI-infused DMS is the automation of mundane tasks, which liberates staff to attend to more pressing responsibilities. For instance, such a system can streamline student enrollment processes, minimizing the resources expended on handling extensive data sets. Moreover, AI capabilities can pinpoint students potentially at the brink of attrition, enabling timely interventions to bolster their academic journey.

Resource management in an AI university would be predominantly anchored on AI-driven data management systems for optimal efficiency (Lemay et al. 2021). AI can play a pivotal role in honing energy usage, minimizing waste, and overseeing inventory and consumption metrics. Additionally, these systems can evaluate student feedback and performance metrics to curate personalized learning trajectories and offer bespoke suggestions for enhancement. The potential of AI-enhanced DMS in a self-sustained university setting is vast, as they equip institutions to refine resource allocation, heighten their receptiveness to student requirements, and elevate academic outcomes (Husna 2022).

Multimodal learning analytics (MMLA) represents a burgeoning domain in higher education. It amalgamates data from diverse sources, presenting a holistic perspective of students' educational experiences (Mangaroska et al. 2020). This analytical paradigm integrates multifaceted data, encompassing visual, textual, and behavioral facets, to glean insights into students' technological interactions and learning modalities (Blikstein and Worsley 2016). By leveraging machine learning methodologies, MMLA can discern patterns and insights related to student education, capturing elements like strengths, areas of improvement, course engagement, and peer and instructor interactions.

MMLA's provision of insightful feedback to educators, coupled with tailored academic recommendations, positions it as a transformative force in higher education. It aids educators in deciphering student learning dynamics, enabling them to adjust instruction to cater to individualized requirements (Pei et al. 2021). Concurrently, students reap the benefits of MMLA through customized feedback and advice, empowering them with insights into their learning proclivities and facilitating informed academic choices (Perveen 2018).

12. Managing with Sensors and Smart Monitoring Systems

Beyond AI-driven data management systems, a smart university can integrate an array of sensors and monitoring systems to collate data on the surrounding environment, students, and infrastructure (Udupa 2022). These amassed data can aid in refining the university's operational strategies, guaranteeing a secure and conducive learning atmosphere. This facet becomes increasingly pivotal if the university maintains physical campuses or opts for a hybrid operational model (Cao et al. 2020). Specific domains warranting monitoring are described next.

12.1. Environmental Monitoring

Sensors can be used to monitor various aspects of the environment, such as temperature, humidity, and air quality. This information can be used to ensure that the temperature and humidity levels are within the optimal range for learning and to identify any potential air quality issues that may affect student health. For example, a study conducted by the Environmental Protection Agency found that poor indoor air quality can affect student performance (Sadrizadeh et al. 2022).

12.2. Student Monitoring

Sensors can also be used to monitor student behavior and activity. For example, sensors can be installed in classrooms to track student attendance and engagement. This information can be used to identify students who may need additional support and to improve teaching practices. Additionally, sensors can be used to track student movement and behavior in public areas to ensure student safety.

12.3. Facility Monitoring

Monitoring systems can be used to track the usage of various facilities, such as classrooms, laboratories, and recreational areas. This information can be used to optimize resource usage and identify areas that require maintenance. For example, sensors can be used to detect leaks in plumbing systems and to identify equipment that requires maintenance.

An organization with sensors and monitoring systems for self-regulation can improve its operations and ensure a safe and comfortable learning environment (Sen 2022; Straw

2020). By gathering information about the environment, students, and facilities, the university can identify areas that require improvement and implement measures to address those areas.

13. Managing for Sustainability

As global communities grapple with climate change and the pressing demand for sustainable energy solutions, enterprises stand at the forefront to set precedents (Nutakki and Mandava 2023; Talaat et al. 2023). AI-powered universities are uniquely positioned to harness renewable energy avenues, minimizing their carbon footprint and championing sustainability. Attaining energy autonomy and endorsing eco-friendliness in such institutions through AI can manifest in several ways:

- AI can elevate the efficiency of energy-intensive systems, fine-tuning the operations of HVAC, lighting, and water systems, thereby curtailing energy usage.
- AI can expedite the evolution of innovative renewable energy technologies, like high-performance, cost-effective solar cells, promoting a shift from fossil fuels to cleaner energy options.
- AI can oversee and strategize around environmental commodities, such as air and water quality, to conceive blueprints that shield the environment and temper our ecological influence.
- AI can foster awareness about sustainability by curating educational initiatives underscoring the significance of sustainable practices and ecological impact minimization, sowing the seeds for a greener global future.

Tapping into AI, a smart university can adeptly maneuver renewable energy deployments. For instance, AI can anticipate energy requirements and modulate the use of renewables, such as solar and wind energy, to meet those demands (Khan et al. 2022). It can also refine energy storage modalities, like batteries, guaranteeing the judicious harnessing of renewable energy (Zhao 2023). Moreover, data centers within the university, notorious for their high energy consumption, can be powered by renewables. AI can fine-tune the energy dynamics within these centers, making adjustments, like modulating cooling mechanisms to conserve energy (Huang and Koroteev 2021). Extending this principle, a smart university's transportation grid can be electrified, with vehicles running on green energy. AI can optimize the deployment of these electric vehicles, forecasting transport needs and tailoring vehicle allocations accordingly (Mischos et al. 2023). By strategically using AI to maximize renewable energy utility, smart universities can drastically slash their energy expenditures, paving the way for a sustainable academic landscape.

14. Robotic Automation for Organizational Effectiveness

The applicability of robotics in education has been a hot topic for over three decades, as evidenced by studies conducted by Inigo and Angulo (1985) and Jaworska and Łaski (1991). An AI-powered university can capitalize on advancements in robotics and smart machines to automate routine tasks, enhance the learning experience, and improve operational efficiency (Esposito 2017). Robots and smart machines can perform various tasks in an AI-powered university. For instance, they can automate routine tasks, such as cleaning, maintenance, and security, freeing up human resources to focus on crucial activities, like teaching and research (Mitra 2019).

Robots can enhance the learning experience of students. For example, they can provide personalized tutoring, monitor student progress, and offer feedback. Additionally, robots can simulate real-world scenarios, such as medical procedures or hazardous situations, to provide hands-on training in a secure environment. Furthermore, robots can improve operational efficiency in an AI-powered university. For instance, they can automate the delivery of supplies, such as books and equipment, and assist with inventory management. They can also aid in research tasks, such as data collection and analysis (Rahman 2021). Some additional examples include:

- Personalized tutoring: Robots can offer personalized tutoring to students, customized to their individual needs and learning styles. This can be especially advantageous for students struggling in a particular subject or requiring extra assistance to keep up with the pace of the class.
- Robotic TAs: Robots can provide students with hands-on learning experiences that are not feasible with traditional methods. For instance, they can simulate real-world scenarios, like medical procedures or hazardous situations, helping students develop the skills required for success in their chosen careers.
- Collaborative learning: Robots can facilitate collaborative learning among students. For example, they can form virtual teams of students from different parts of the world to work together on projects. This can help students develop the teamwork skills required in the workplace.
- Assessment: Robots can assess student learning in various ways. For example, they can administer quizzes, provide feedback on assignments, and even grade papers. This can save teachers time and provide students with more timely feedback on their work.
- Food preparation and delivery on campus: Robotic processes have already become mainstream alternatives for (fast) food preparation and delivery.

All of these indicate the significant role of robotics and smart machines in an AI-powered university. By capitalizing on the advancements in robotics and smart machines, universities can create a more efficient and effective learning environment (Oravec 2023).

15. Managing Equity and Access: A Path for HBCUs

Artificial intelligence holds the promise to dramatically improve equitable access to education by offering personalized learning pathways, diminishing geographical constraints, and addressing the socioeconomic hurdles confronted by students globally. AI-enabled adaptive learning platforms can customize educational materials to fit individual students, catering to varied learning approaches and ensuring a bespoke academic journey for each learner (Luckin and Holmes 2016). Moreover, AI-integrated virtual tutors can furnish students in distant or underserved regions with premier educational tools, thereby leveling the playing field in terms of educational accessibility (Bakshy et al. 2015). As the terrain of higher education undergoes transformation, historically Black colleges and universities (HBCUs) are presented with a golden opportunity. They can harness these emerging technologies, not just to maintain their competitive edge and aptly address future educational paradigms, but also to democratize education for traditionally marginalized groups (Mireille et al. 2023). By adopting AI-driven approaches, HBCUs can elevate their academic programs, broaden access to pivotal resources, and cultivate a milieu that champions innovation.

HBCUs should earmark substantial investments in AI infrastructure, encompassing high-performance computing assets, sophisticated data storage solutions, and state-of-the-art research amenities. Such infrastructure will pave the way for HBCU faculties and students to delve into pioneering endeavors in AI, machine learning, and cognate domains. Establishing alliances with industry stalwarts and fellow academic entities can position HBCUs at the vanguard of technological evolution, simultaneously unlocking invaluable networking avenues for their academic community.

Curricular evolution is pivotal in the march toward an AI-augmented future. HBCUs should embed AI-centric modules in their academic portfolios, spanning rudimentary programming and data analytics to intricate machine learning and AI ethics. Such curricular inclusions will not only arm students with contemporary skills for the evolving job market but also stimulate cross-disciplinary academic synergies.

Beyond tangible infrastructure and curriculum redesign, HBCUs ought to instill an ethos of innovation by inaugurating specialized AI research hubs and championing entrepreneurial zeal within the academic precincts. Provisions like incubation centers, mentorship avenues, and financial endorsements can galvanize the ascent of AI-centric startups and inspire the academic community to probe the commercial facets of their scholarly pursuits. Such initiatives can not only elevate the institutional stature in the academic panorama but also invigorate local and broader economic matrices.

Integrating AI-centric modalities in HBCUs will not merely heighten their competitive edge but also capacitate their scholars and educators to sculpt the AI horizon (Livingston et al. 2022). Through strategic infrastructure investments, curricular revamps, and the nurturing of an innovative spirit, HBCUs can anchor their significance in the dynamic realm of higher education, thereby making pronounced contributions to the AI domain and its multifarious applications.

16. Academic, Administrative, and Managerial Challenges

The incorporation of AI technologies into universities can usher in notable advancements in higher education, such as personalized learning trajectories, heightened accessibility, and refined administrative processes (Adams et al. 2023; Gašević et al. 2023). Yet, as with any nascent technology, some inherent challenges and concerns necessitate scrupulous consideration (Busol 2015; Hwang et al. 2020).

A salient apprehension revolves around the potential redundancy of administrative and academic staff. As AI systems undertake roles like paper grading, course scheduling, and other administrative tasks, this could profoundly impact the livelihoods of those displaced and reshape the university's foundational structure. Another concern is the potential erosion of educational caliber. While AI possesses the prowess to personalize and offer timely feedback, it lacks the nuances of face-to-face interactions between students and educators. The irreplaceable human element, characterized by mentorship and spontaneous interactions, remains beyond AI's reach. Students could thus miss out on the myriad benefits of active participation in a vibrant academic milieu. There are also looming concerns over data protection, potential algorithmic bias, and the ability of AI to grapple with nuanced issues demanding human discernment, like ethical dilemmas, multifaceted research, and critical thought.

It is paramount to recognize AI's dual nature: although it can democratize access, it could also inadvertently hamper equitable education. Biases embedded within algorithms might inadvertently reinforce existing disparities, perpetuate stereotypical viewpoints, or unduly prejudice certain demographics (Eubanks 2018). Consequently, scholars, educators, and policymakers must unite in addressing these challenges, ensuring that AI educational instruments are conscientiously developed with an emphasis on equity and inclusivity (Mittelstadt et al. 2016).

While AI-enhanced academic environments present transformative possibilities, the potential pitfalls associated with their integration cannot be overlooked (Xia et al. 2023). Universities ought to adopt a calculated and holistic strategy in AI assimilation, weighing the prospective impacts on their staff, student body, and the broader academic sphere.

17. Discussion

AI holds the promise of significantly reshaping higher education and university systems (Bakhshi et al. 2016). AI applications, when powered by quantum technologies, present a new array of opportunities for the upcoming smart universities (Seskir and Willoughby 2023). Quantum computing, with its unprecedented computational capabilities, has the potential to enhance AI applications, making them more effective and efficient (Taylor 2020). This can lead to refined educational algorithms that cater to personalized learning pathways, optimally allocating resources and curating highly individualized educational experiences. Such advanced AI applications can also manage administrative tasks at a level of complexity and speed currently unattainable with classical computing. Moreover, these technologies can unlock new ways of data analysis, enabling better student performance tracking, prediction, and intervention strategies. Revolutionary strides in these fields promise to add a new dimension to the way smart universities operate, improving both their academic and their administrative realms.

We saw that AI has already made a considerable impact on higher education, as numerous universities have embraced AI-powered technologies to optimize administrative processes and enrich student learning experiences. For instance, chatbots and virtual assistants already offer students instant access to information and support, while AI-powered grading and feedback systems expedite the evaluation process for educators (Winkler and Söllner 2018). Moreover, AI algorithms are extensively used to tailor learning experiences for students based on their learning styles, performance, and interests, facilitating better outcomes (Zawacki-Richter et al. 2019).

The literature review led us to identify several key themes and subthemes. These themes are presented in the form of a table, which also highlights different offices and functions of the future university (see Table 1).

Table 1. A summary of key themes in the literature on AI adoption in higher education.

Key Office	Sub-Office	Function	Sub-Function
1. AI-Driven Admissions Office	1.1 AI-Based Application Screening	Efficient application processing	Automated evaluation and scoring
	1.2 AI-Assisted Interview Scheduling	Streamlined interview process	Calendar syncing and reminders
	1.3 AI-Powered Financial Aid Assessment	Fair and accurate financial aid distribution	Evaluation of financial aid applications
2. Intelligent Tutoring and Learning Center	2.1 Personalized Learning Paths	Customized education experiences	Adaptive course recommendations
	2.2 Virtual Classroom Assistance	Real-time support in virtual classrooms	AI chatbots and virtual teaching assistants
	2.3 Peer Collaboration Tools	Enhanced student collaboration	AI-facilitated study groups
3. AI-Enhanced Research and Development Department	3.1 AI-Driven Research Collaboration	Efficient research partnerships	AI matching of research interests
	3.2 Automated Literature Review	Accelerated literature analysis	AI-powered article summarization
	3.3 AI-Assisted Data Analysis	In-depth data processing and interpretation	AI-driven data visualization tools
4. Virtual Learning Environment Management Office	4.1 Immersive Learning Experiences	Engaging and interactive education	AI-powered virtual reality simulations
	4.2 Digital Content Curation	Tailored learning materials	AI-generated content recommendations
	4.3 Virtual Learning Analytics	Continuous improvement of virtual learning experiences	AI-driven learning outcome predictions
5. Automated Administrative Services Center	5.1 AI-Powered Scheduling	Optimized scheduling and resource allocation	Automated course and exam scheduling
	5.2 AI-Assisted Student Services	Efficient student support	AI-driven chatbot for inquiries
	5.3 Automated Document Processing	Streamlined paperwork processing	AI-powered form completion and validation

Table 1. *Cont.*

Key Office	Sub-Office	Function	Sub-Function
6. AI-Powered Career Counseling and Placement Office	6.1 AI-Based Job Matching	Personalized career guidance	AI-driven job and internship recommendations
	6.2 Virtual Interview Preparation	Enhanced interview readiness	AI-powered mock interviews
	6.3 AI-Enabled Networking Platform	Expanded professional connections	AI-facilitated networking events
7. AI-Enabled Campus Security and Surveillance Office	7.1 AI-Powered Surveillance System	Improved campus safety	AI-driven monitoring and threat detection
	7.2 AI-Based Emergency Response Management	Efficient emergency management	AI-assisted crisis prediction and response
8. AI-Assisted Facilities and Resource Management Office	8.1 Smart Energy Management	Sustainable energy consumption	AI-driven energy optimization
	8.2 AI-Enhanced Space Usage	Optimized space allocation	AI-powered room scheduling and tracking
9. Data-Driven Curriculum and Assessment Design Department	9.1 AI-Based Curriculum Design	Relevant and engaging curricula	AI-driven course evaluation and updates
	9.2 Automated Assessment and Feedback	Accurate and timely student evaluations	AI-powered grading and feedback
10. AI-Centered Collaboration and Innovation Hub	10.1 AI-Enhanced Idea Generation	Fostering creative collaboration	AI-driven brainstorming tools
	10.2 AI-Powered Project Management	Efficient project coordination	AI-based task allocation and tracking
	10.3 AI-Assisted Cross-Disciplinary Networking	Facilitating interdisciplinary connections	AI-driven collaboration recommendations

Our exploratory analysis, grounded in both historical and current scholarly works, confirms the transformative impact of AI on the higher education landscape. We have successfully delineated the broad array of applications and potentials of AI in forging the framework of future smart universities. By curating a comprehensive structure, as illustrated in Table 1, we have illuminated the myriad of functionalities. The identification and categorization of key themes, subthemes, and associated functions in the table underscore our comprehensive approach to understanding the AI-driven evolution of higher education. Our findings substantiate our initial presumption about AI's capability to revolutionize both academic and administrative facets of educational institutions. To this extent, the objectives set forth at the onset of this study have been achieved, providing a holistic view of the transformative potential of AI in higher education.

18. Conclusions

Although AI's impact on higher education continues to unfold, its potential to transform learning and research methods is evident. However, responsibly implementing AI necessitates careful examination of its potential advantages and risks, along with a commitment to fulfilling all students' and stakeholders' needs (Luckin and Holmes 2016). By engaging in discussions about AI's ethical and social implications in higher education, we can harness its potential to improve learning outcomes, while mitigating the risks and challenges it poses.

We have seen how emerging smart universities will use advanced AI and potential quantum computational advantages to construct an education ecosystem where automation is predominant. Nonetheless, the integration of AI in higher education comes with challenges. A primary concern is job displacement potential, as AI systems can automate numerous tasks previously performed by humans (Brynjolfsson and McAfee 2014). This could result in substantial changes in higher education employment, with many jobs becoming obsolete or demanding new skills. Another worry is algorithmic bias, where AI systems might exacerbate existing educational inequalities by replicating and reinforcing biases present in training data (Barocas and Selbst 2016). Hence, universities and educational policymakers need to engage in comprehensive and inclusive discussions about AI's role in higher education and devise guidelines and best practices for its responsible use (Crawford and Calo 2016). This encompasses ensuring AI systems' transparency and accountability, as well as protecting data privacy and security. Additionally, it entails addressing algorithmic bias issues and taking steps to guarantee the fair distribution of AI benefits.

Employers' and industries' acceptance of degrees from an AI-centered smart university will depend on several factors, including the university's reputation, education quality, specific skills and knowledge acquired by students, and the perception of AI-centered education in the job market. Automated systems risk bias, potentially leading to discriminatory practices in grading, admission, and hiring (Grgić-Hlača et al. 2022). Furthermore, learners may lack interpersonal skills and social experiences associated with traditional classroom education, which could hinder their ability to collaborate and communicate effectively with others. Additionally, some employers might perceive AI-centered degrees as inferior to those from conventional universities, impacting graduates' job opportunities and career prospects.

In the light of the AI-driven smart universities of the future, administrative, management, and strategic implications are paramount considerations. Administratively, the introduction of AI technologies will necessitate a reevaluation of existing processes and structures, necessitating the creation of new roles or alterations to existing ones to effectively manage these technologies. From a management standpoint, this transformation requires careful, strategic planning and implementation to ensure the seamless integration of AI technologies, while managing potential risks. Concerning change management, the shift toward AI-integrated systems will be a considerable change requiring effective communication, stakeholder engagement, and continuous monitoring to ensure that the transition is smooth and beneficial for all parties involved. Leaders will need to address employees' concerns about job displacement and provide necessary training and support to help them adapt to new roles and responsibilities. Strategically, the advent of AI-driven smart universities calls for a paradigm shift in higher education. It requires redefining the education delivery model, reimagining the roles of educators and administrators, and establishing strong partnerships with technology providers. The strategy should also account for potential biases and ethical considerations inherent in AI technologies, ensuring that they are implemented in a manner that promotes fairness and inclusivity.

As AI becomes increasingly integrated into higher education, it is crucial to continue these discussions and adapt strategies to ensure the responsible use of AI, while maximizing its potential to enhance learning outcomes. This will necessitate an ongoing commitment from all stakeholders—educators, administrators, policymakers, and students alike—to shape the future of higher education in a way that is equitable, effective, and truly transformative.

Before winding up, certain significant limitations of this study should be mentioned. One, because the issue is still somewhat futuristic, real-world case studies or original data from the field of practice were unavailable to examine the many hypotheses and assertions mentioned in the text. As more universities use AI tools and methodologies strategically, we plan to pursue this goal in a future research effort. Two, scholarly publications are only now beginning to recognize this as an area of study, so we had to borrow ideas and notions from the popular press. Given the lack of comprehensive peer review, the validity of the claims made in these should be regarded with caution. Third, the authors of this manuscript come from the disciplines of education and management; while this provided us with a unique perspective, our examination of the technical side of AI was limited. We hope future researchers can reexamine the topics covered in this manuscript from a predominantly technical standpoint.

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